Water Purification by Acoustically-Induced Particulate Agglomeration

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Introduction

Although fusion power generation may soon make industrial-scale water desalination/purification more practical, the energy-intensive process of desalination and water distillation in general means that potable drinking water remains out of reach for many.

Reverse osmosis filters are expensive and require frequent changing with their manufacture being energy-intensive in its own right. Although solutions that require zero power consumption at the site of purification are tempting, separating mixtures of particulates in any fluid requires energy. There is no way to separate the components of a mixture without the use of at least some energy.

Abstract

Rather than a solution that calls for huge amounts of energy to be expended in advance to make it possible for an end-user to expend zero energy, the increasing availability of electricity in even the poorest areas as well as the possibility of utilizing a small photovoltaic unit means that a low but non-zero energy approach stands the greatest chance of success.

With this sort of objective in mind, I would put forth the notion of the use of simple plastic buckets with what is essentially a waterproof speaker with a metal plate over the outside replacing the bottom of the bucket. The generation of just any sound would not, in and of itself, have a substantial impact on the solid particulates within a sample of water. However, with the addition of a simple, low-cost programmable microchip, patterns of sound emitted at calibrated intervals and frequencies could be used to induce microfluidic locomotion of individual particles of varying size and composition one wishes to remove.

For every particle found in a raw water sample, be it sea water, ground water, river water, or even sewage, each of the thousands of different particle types have different densities and sizes. Each particle type, therefore, has a corresponding frequency, intensity, and pulse interval of sound that would induce maximal microfluidic motion within an aqueous environment.

Before getting into the more complex topic of crafting patterns of sound ideal for water purification, I will first explain this concept in its simplest form.

All physical objects (solids and fluids both) conduct sound at a rate of speed that is higher the greater the density of the material. Distilled water conducts sound at a given speed while the particulates found in that water, since their density is necessarily higher, conduct sound at different rates based upon their own, individual densities.

If a sound wave propagates through a fluid that includes particulates that are of greater density than the surrounding water (as most water does) then on the micro-scale, the portion of that sound that passes through the particle of sodium chloride, for instance, will begin moving at a higher rate of speed than the other parts of the wave. The sound exiting the sodium chloride (or any other particle in the mixture) exits ahead of the wavefront, creating an area that is devoid of a propagating wave.

The act of the wave striking the particulate does not alter its relative position within the mixture, however, when the wave has finished passing through the particulate, the majority of the wave, which has not been accelerated, seeks to occupy the now void section of the wavefront much like troops in an ancient war rushing in to fill the ranks of a battle formation in a space where a comrade had fallen.

As this sound propagates in a direction that is perpendicular to the general direction of motion, its momentum causes it to continue to curve into a sort of rip tide. This rip tide would physically propel the particulate in the exact opposite direction of the direction of travel of the primary sound wave. With repeated pulses, particulates would collectively move, in our contraption, toward the sound-emitting insert fitted into the bottom of the bucket.

After being in operation for a few minutes, the water floating at the top of this bucket would be of a relatively high degree of purity and potable water could be siphoned from near the surface until one is left with only the undesired material in the bottom.

If enough of the particulates in the overall body of water come within sufficient proximity, rather than tending toward diffusion, a sort of congealing would occur in the presence of the tailored acoustic environment. Before long, all of the elements of the raw water that are not H2O would be collocated at the bottom of the bucket for easy disposal.

The small microchip becomes necessary as a pre-programmed sequence of sounds must be emitted in a particular pattern in order to generate microfluidic currents for particulates of a variety of sizes and densities. The larger the particle one is trying to actuate acoustically, the more rapidly and efficiently it can be made to move. Most water consists of particles ranging from nanometers in diameter to sizes that are visible to the naked eye. Although exhaustive testing will be required to establish the precise frequency settings ideal for each particle size and type, we can start off by making some general predictions that can guide development.

The first such prediction would be that the very smallest of particles would require the highest frequency of sound to be effectively moved in these micro-increments. If the goal is the eventual rapid movement of such small particles to one side (i.e. the bottom) of the bucket, the nano-scale particles need to "hitch a ride with" the micro-scale particles and the micro-scale particles need to hitch a ride with larger particles such as salts that can act as both a nucleus and a means of conveyance. If the macro-particles are segregated out of sequence i.e. first instead of last, then the water will become substantially

more difficult to purify using this method. In short, we must congeal the small particles first without perturbing the large ones, and then expand the range of frequencies in a sequence of frequencies so that a sort of nucleation can be achieved.

To purify a given body of water, therefore, the best approach would seem to be the emission of high-frequency pulses exclusively for the first 30 seconds or so. Those initial pulses would not be one continuous tone, but rather, pulses where sound is emitted for about 1/20th of a second and halted for about the same interval on a repeating basis.

In the nano-particulate phase, which, as I mentioned, should require about 30 seconds, the sound is tailored to exclusively act upon the very smallest of particulates such as viral or bacterial components as well as metallic components such as lead which one would remove.

As the system transitions to the micro-particulate phase, lower-frequency sounds are gradually incorporated in sequences. Over a period of perhaps five minutes, the 1/20th second pulses transition from a single, high-frequency tone to the alternation between two, then three, then four, and eventually 10-20 different tones.

As this overall sequence progresses, there would eventually be a range of frequencies emitted in each pulse group, starting with the highest and immediately followed by the lowest. For instance, the high-end pulse might be 2500Hz and the low-end 25Hz. At the final stage of acoustic particulate separation, a 2500Hz pulse is emitted that lasts for 1/20th of a second followed by the minimal frequency in the group (to minimize counter-actions,) followed by 2000Hz, then 35Hz, and so on, bouncing between the highest and lowest bound of the remaining values not yet emitted in that cycle. Sound of some sort is being constantly emitted in all phases except the initial phase in which 2500Hz sound is alternated with silences.

Once the step in the process is reached in which a broader range of frequencies is called for, periods of total silence are not required; only that no single frequency is emitted for more than 1/20th of a second at a time.

Here is a specific example of some sequences with all pulses 1/20th second each that I believe might be effective:
2500Hz - Pause - 2500Hz (repeat for 30s)
2500Hz - 2000Hz - 2500Hz (10s)
2500Hz - 1800Hz - 2000Hz - 2500Hz (10s)
2500Hz - 1500Hz - 2000Hz - 1800Hz - 2500Hz (10s)
2500Hz - 1300Hz - 2000Hz - 1500Hz - 1800Hz - 2500Hz (10s)
2500Hz - 1000Hz - 2000Hz - 1300Hz - 1800Hz - 1500Hz - 2500Hz (10s)

... and continuing along these lines until many frequencies all the way down to 25Hz are covered. The highest frequency would be emitted at a volume of perhaps 5dB and each frequency would be a couple of dB louder as the particles being moved are larger and thus heavier

If successful, clumps should form in the water that are visible to the naked eye that are seen rapidly falling to the bottom of the bucket. After running for a few minutes, the topmost 90% of the water in the bucket; even if the water was filthy to start with; would contain virtually zero particulates and may even be cleaner than single-distilled water.

Conclusion

While this proposal still requires experimental verification, it may be an ideal solution to the problem of securing safe drinking water in a growing range of localities effected by water table contamination.